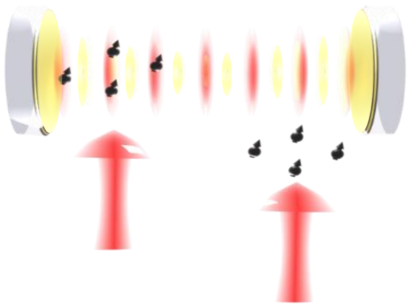
Developments for a continuous superradiant laser on ytterbium (^{171}Yb) clock transition

Jana El Badawi[1,2], Martina Matusko[1], Martin Hauden[1], Francisco Sebastian Ponciano-Ojeda[1], Bruno Bellomo[2], Marion Delehaye[1]

[1] Institut FEMTO-ST, CNRS UMR 6174, UFC, Besançon, France
[2] Institut UTINAM, CNRS UMR 6213, UFC, OSU THETA, Besançon, France

Email: jana.elbadawi@femto-st.fr

Frequency standards based on atomic clock transitions in the optical domain can reach fractional frequency stabilities of 10^{-17} at one second of integration[1]. Such remarkable performances could be further improved by superradiant lasers operating on atomic clock transitions, that can become the next generation of optical frequency references[2]. Superradiance is a phenomenon in which multiple atoms emit light collectively, producing a pulse of radiation characterized by a short duration and a high intensity compared to emissions from individual atoms[3]. Superradiance occurs when atoms interact with each other within a common electromagnetic field, that is typically provided by a Fabry-Perot cavity in the optical domain. In several recent experiments, pulsed optical superradiant emission was observed[4,5] and the next objective is to reach a steady state of continuous emission. Several approaches are considered, which include confining atoms in an optical lattice potential with a constant inversion on the optical clock transition[2] or an atomic beam passing through the cavity that provides a constant reloading of atoms[6].



Here, we present experimental and theoretical developments towards another approach, which is the sequential transport of confined ^{171}Yb atoms into a Fabry-Perot cavity for two-site operation[7]. We work to create an optical conveyor belt in order to transport the atoms from a magneto-optical trap with $N > 10^7$ atoms at temperatures below 100 μK. Experimentally we have a distance of ~ 30 cm to the cavity where atoms can then generate superradiance on the narrow ($\Gamma = 7$ mHz) $^1S_0 \rightarrow {}^3P_0$ clock transition at 578 nm. Using a theoretical model of such an open quantum system, we are able to perform numerical simulations of the systems dynamics. We can then explore the behavior of the system in the parameter space and study the characteristics of this superradiant laser, such as its frequency dependence and its stability.

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